THE ROLE OF SCRUB JAYS IN PINYON REGENERATION

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INTRODUCTION

Pinyon-juniper woodlands occupy 19.4 million hectares in the United States and are found primarily in Nevada, Utah, Arizona, New Mexico, and Colorado (Eyre 1980). Much of Northern Arizona at elevations between 1370 and 2440 m contains the Colorado pinyon (<u>Pinus edulis</u>) and various species of juniper (<u>Juniperus osteosperma</u>, <u>J</u>. <u>monosperma</u>, <u>J</u>. <u>deppeana</u>, and <u>J</u>. <u>scopulorum</u>).

Attitudes about the value of pinyon-juniper woodlands have recently changed from the woodlands being regarded mainly as a hindrance to cattle grazing in the 1950's and 1960's to instead being viewed as a valuable resource starting in the 1970's. This change in attitude came about primarily because of the increased demand for using pinyons and junipers as firewood and the collections of large crops of pinyon nuts (Lanner 1981). Consequently, interest has been directed toward pinyons and their silvicultural requirements. Recent research has revealed different aspects of pinyon ecology, but factors regulating pinyon regeneration are still poorly understood.

While most pines produce small, lightweight seeds adapted for wind dispersal, the pinyon produces large, wingless seeds which do not fall beyond the crown of the parent tree (Meagher 1943, pers obs.). Instead, the pinyon relies on animals as its dispersal agents. It has coevolved with several species of Corvids so that the cone and seed's morphological structure and the seed's high energy content make it a highly desireable and an

easily accessible food source. The birds benefit the tree by caching seeds during years with large cone crops, leaving some of them in favorable germination sites (Vanderwall and Balda 1977, 1981, Ligon 1978).

Four species of Corvids are known to harvest, eat, and cache pinyon seeds. Two species, Clark's nutcrackers (Nucifraga columbiana) and pinyon jays (Gymnorhinus cyanocephalus), harvest enormous quantities of seeds. Clark's nutcrackers near Flagstaff, Arizona transport them long distances and cache them in the higher elevation range of the mixed coniferous forest in the San Francisco peaks. Pinyon jays are either residents of ponderosa pine forests or of pinyon-juniper woodlands, so they cache the seeds in both localities. Steller's jays (Cyanocitta stelleri) living in the lower range of the ponderosa pine forest have been observed harvesting and caching pinyon seeds which they transport to the ponderosa pine forest. Those living above this lower range of ponderosa have not been seen harvesting pinyon seeds (Vanderwall and Balda 1981).

With the exception of the pinyon jays living in pinyon-juniper woodlands, most pinyon seeds are taken out of their normal elevational range by these Corvids. Some germinate and survive. Although this type of dispersal is important in introducing pinyons into different habitats, it is not very influential in local regeneration.

Scrub jays (Aphelocoma coerulescens) are permanent residents of the pinyon-juniper woodland. They eat a wide variety of food so are not as dependent upon pinyon seeds as the other Corvids.

Their morphological characteristics and behavioral patterns are not as specialized for harvesting and caching the seeds (Vanderwall and Balda 1981), but since they live permanently within pinyon pines and junipers and cache substantial numbers of pinyon seeds there, they appear to be important in local regeneration of pinyon.

Observations have been made on scrub jay caching behavior and on some characteristics of their cache sites. They usually cache one seed per cache, though they have been observed carrying up to four seeds per trip, with an average of 2.3 seeds. Seeds are often cached within 1 m from each other, and cache sites have been found primarily along edges of tree trunks and stumps (Vanderwall and Balda 1981, Balda 1987). However, little is known about the scrub jays' influence on pinyon regeneration. The extent to which scrub jays cache pinyon seeds, the locations of their caches, the conduciveness of the cache sites for germination, and the outcome of these caches--whether they are dug up by the birds or other seed predators or whether they are left to germinate--are important for determining scrub jays' impact on pinyon regeneration.

STUDY AREA

The study area is located 25km east of Flagstaff, Arizona, near Winona. The site is approximately 33 hectares in size, 3 hectares running in a north-south direction, and 10 hectares

running in a east-west direction. The northern edge of the site is adjacent to Forest Service road #128. Several long, narrow meadows run in a east-west direction within the site. Rabbit brush <u>Chrysothamnus mauseosus</u> predominates within the meadows; Apache plume <u>Fallugia paradoxa</u> is also present in the meadows but to a lesser extent. The trees within the site consist exclusively of pinyon (<u>Pinus edulis</u>) and juniper (<u>Juniperus monosperma</u>). The terrrrain is fairly level. The soil type in this region is Lithic Ustorthent.

Winters are relatively mild with sporadic winter storms bringing transient snow cover. Even after large storms, snow melts from directly underneath the trees within a few days. South-facing slopes and areas directly north of the meadows also soon become devoid of snow cover. Most snow is gone from the area within a week of a storm. Snow permanently disappeared from the study area in mid-March.

MATERIALS AND METHODS

CACHING

The fall of 1986 was primarily spent observing scrub jays in the study site. Jays were extremely difficult to observe within the trees since visibility was limited and the birds repeatedly flew away from the observer. Consequently, all of the observations were made from the meadows, and practically all of

the observed caches were within or near the edge of the meadows. 7 x 35 binoculars were used for all recorded observations of the birds.

When a scrub jay was observed making a cache, the cache was numbered, a nearby tree was flagged to relocate the cache site, and a map was drawn of the cache location in relation to vegetation, rocks, and other nearby features. All observations about the behavior of the jays before, during, and after caching were recorded.

Various parameters for each cache site were recorded which included the location of the cache site, whether the site was in a meadow or on the north or south side of a meadow, and the type of vegetation it was nearby or under. Measurements of each cache site included distance of the cache from the trunk of the tree it was under, compass orientation of the site with respect to the trunk, percent crown density, and amount of litter at the site.

Beginning in March, when the snow had receded enough to continually see the substrate, weekly observations of each cache site were conducted. Any depressions in the terrain, indicating excavations by either birds or rodents, were recorded. Since rodents gnaw on the pinyon shells to open them, the edges of the shells were cut at an angle. Also, incisor marks were visible on the shell's surface. Pinyon seeds opened by birds had neither of these characteristecs. The number of opened pinyon seeds at or near each site was recorded as well as whether they were opened by birds or rodents. These weekly observations continued through the end of July. Several sites had continual high activity as

indicated by large numbers of opened pinyon seeds and many depressions in the terrain, while other sites had little to no activity throughout the spring and summer. Only one site under a juniper had high activity, so comparisons were made between sites under pinyons. The sites under pinyons with high activity were designated "popular" trees, and those with little to no activity were designated "unpopular" trees. Seven of the most popular pinyons were compared to seven of the least popular pinyons by using a Mann-Whitney U test. Tree height, diameter, location, and depth of litter were compared for the two categories of trees.

In early September, 1987, all the cache sites were dug up, and the dirt and litter was sifted through a screen with a 5mm mesh. Any pinyon seed remaining would be too large to fit through the mesh and would be visible to the observer. Cache sites having either pinyon seedlings or pinyon seeds were recorded.

PREDATION AND GERMINATION OF PINYON SEEDS

In early November, 50 pinyon seeds were buried under either pinyons, junipers, or bushes at the same depth as the seeds cached by scrub jays. This was done to determine the effects of predation by rodents. In March these sites were dug up in the same manner as described for the natural caches. A more in depth experiment of the effects of predation on germination was then

begun and is described below.

In March an experiment was initiated on the germination of pinyon pines with respect to locations of pinyon seeds and protection of the seeds from predation. Since jays were observed to cache in three general vegetation types, under tree canopy, within or near bushes, and completely out in the open, 250 pinyon seeds were planted in each of the respective habitats. Also, since predation of cached seeds by rodents appears to be an influential factor, 250 additional seeds were planted in each of the three habitats under a protective screen. All seeds were planted 2cm below the surface, which was the depth observed of the scrub jay caches, and all seeds were handled with plastic gloves to keep human scent off of the seeds.

The unprotected seeds planted under tree canopies of mature pinyons were planted 1 meter apart in a grid pattern. The 1 meter distance between seeds was felt to be far enough apart so that a rodent would not be influenced in finding a seed based on the location of a previous seed. Four grid plantings were under four groups of pinyons. The seeds planted under protective screens were under different pinyons but were within the same area. They were under three screen cages, 100 under two of the cages, and 50 under one cage. These seeds were planted 10cm apart. They needed to be closer so that the use of the cages would be feasible. Since only germination and not longevity of the pinyons was under study, the closer distance between plantings was felt to have a minor influence on the differences in germination between the two categories. The screen was of a

fine aluminum mesh stapled over the wooden frame of each cage. The screen penetrated 30cm below the surface on each side so no rodent would go under the screen.

The seeds planted near bushes were planted four to a bush, one on each side. Most of the bushes were rabbit brush, a few were Apache plume. The protected seeds were planted under four cages, two on the north side and two on the south side of the bushes. They were also planted in a grid pattern with each seed 10cm apart. All the seeds planted near bushes were in the same general area.

The seeds planted in the open were planted 1 meter apart along 5 transects with 50 nuts in each transect. Each transect was positioned so that all of the transects were a meter or more from any large vegetation. The protected seeds in the open were under three cages, planted in a grid pattern, 10cm apart. They were planted in the same area as the transects and were also at least a meter from large vegetation.

DISTRIBUTION OF YOUNG PINYONS

A survey of the locations of young pinyon pines was conducted in three separate areas within the study site. Each area consisted of a section of meadow with pinyons and junipers to the north and to the south of the meadow. The length and width of each area was recorded, and the area was combed to determine the location of each young pinyon less than 5 feet

tall. Each area contained 100 young pinyons which were categorized according to whether they were under or less than one meter from a pinyon, a juniper, or a bush, or whether they were a meter or more from any large vegetation. The abundance of each vegetation type was then quantified by making 200 recordings of vegetation type for each area. These recordings were made at two meter intervals along five transects for each area. The locations of young pinyons were then compared to the abundance of each vegetation type. A survey of the locations of young pinyons within tree canopy was also conducted. A comparison was made between the locations of young pinyons in the three areas surrounding meadows and in tree canopy. Chi-square and analysis of variance tests were used to analyze the results.

RESULTS

CACHING

The 1987 cone crop of pinyons was extremely large within the study site and throughout the pinyon-juniper woodlands in north-central Arizona. Out of 29 adult pinyons sampled in the Winona area in the fall of 1987, Christensen (unpublished data) found an average of 377.8 cones per tree (SD=374.9, SE=65.6). The cones opened in mid-September. At this time seeds were not only easily available in the opened cones, but seeds fell out of the cones onto the ground so that hundreds of seeds were lying under the

canopy of many pinyons. By the middle of October, the availability of edible seeds had noticeably diminished. The cones at the tops of pinyons and at the outermost branches either were empty or only contained aborted seeds. The majority of seeds remaining on the ground also were aborted. By early December no edible seeds were found either in the trees or on the ground.

Recorded observations of caching by scrub jays were made from September 28 to December 5. Based on the number of observations of scrub jays, caching was likely to have occurred prior to September 28 but little to no caching occurred after December 5. Sixty-two caches were recorded and mapped; most of the caches occurred in October. Caching was observed by lone birds but more frequently by groups of 2-5 birds. The average number of birds observed caching was 3. Intensity of caching varied greatly. Some days little to no caching was observed even though many pinyon seeds were available. At other times jays would cache intensively. Birds appeared to cache more intensively when the weather was cold and calm and least intensively when it was either windy or warm. A decrease in activity during windy or warm days is characteristic of most bird species. The distance between the extraction of a seed and the subsequent cache location also varied greatly. For three of the recorded caches the jay picked a seed from the ground and cached it less than a meter away. Usually, the jay would extract a seed from a cone and then fly a distance to cache it. The farthest distance between seed extraction and caching was 84m. The

average distance was 32.5m (+/-SE 6.63, n=24). Approximately 20% of the time a jay known to have extracted a seed would fly out of sight, so no measurement could be made. Consequently the flying distance is much farther than these figures indicate. Approximately 15% of the seeds cached were taken from the ground; the rest were extracted from cones in the trees. This figure is probably uncharacteristically high since viable seeds are rarely available on the ground during an average year.

On five occasions large groups of pinyon jays were observed moving through the study site harvesting pinyon seeds. At other times they could be heard at a distance but were not in the study site. These observations were made between early October and mid-November. The pinyon jays were much more diligent at harvesting seeds and undoubtedly decreased the number of remaining pinyon seeds substantially.

DESCRIPTION OF CACHE SITES

Thirty-seven caches were under tree canopies; 29 of these were under pinyons and 8 were under junipers (figure 1).

Twenty-five cache sites were not under tree canopies. Of these, 8 were near a bush, either rabbit brush or apache plume; 3 were within or nearby logs; and 14 were out in the open, more than 1 meter from any large vegetation.

Significantly more caches were under pinyons than in any other vegetation habitats (X^2 =32.76, p<.001). Differences

between the number of caches under tree canopy and not under tree canopy were not significant (X^2=2.32, $0.1<p<0.25$).

Cache Sites Under Canopy

The average distance of the cache to the nearest tree trunk was 1.5m. The orientation of the caches to the trunk was as follows: 9 caches were northeast of the trunk, 1 cache was northwest of the trunk, 16 caches were southeast of the trunk, and 11 caches were southwest of the trunk. The orientations of caches were significantly different (X^2 =14.05, $p<0.005$). The majority of caches (27 out of 37) were south of the trunk. Most of these were in the southeast quadrant (figure 2).The average depth of litter below the trees was 1.8cm. The amount of overhead cover above the cache sites was estimated using printed crown density scales as a reference (Avery 1978). Nine sites had 1-40% crown density, 24 sites had 41-70% crown density, and 4 sites had 71-100% crown density.

CACHE LOCATIONS IN RELATION TO MEADOWS

All of the cache sites under trees were along the meadow boundary or very near the boundary. This is primarily due to the extreme difficulty in observing and following jays within the trees.

Thirty of the caches under trees were on the north edge of the meadows where snowmelt is rapid. Five were on the south edge of the meadows, and 2 were within the trees, not at the meadow's edge (figure 3). The differences between the number of caches on the north and the south sides of the meadows were significant ($X^2 = 17.86$, $p<0.001$).

Twelve of the caches in the meadow were on the north side, 7 were in the middle, and 6 were on the south side. The number of caches on the north side of the meadow were not significantly different from those on the south side ($X^2=2.00$, $0.1<p<0.25$), (figure 4).

OUTCOME OF CACHES

Upon excavation in September, 5 cache sites (8% of the total) were found still containing pinyon seeds. Four of these were under pinyon canopy, all 4 had germinated. Of these 4 caches, 3 were on the north side of the meadow, 1 was on the south side. Three were southeast and 1 was northeast of the tree's trunk. The average distance from the trunk was 1.75m (3m,1m,2m,1m); the average litter depth was 1.8cm (0.5cm,2cm,2cm,3cm). Three caches had 41-70% crown density, and 1 cache had 1-40% crown density.The fifth cache was in the open and had not germinated.

The seeds found in these caches along with seeds found in other caches previously dug up were approximately 2cm below the

surface, at the junction between the tree's litter and the soil underneath.

These data can be compared to those of the 50 planted seeds. Upon excavation of these seeds, 6 seeds remained (12% of the total); 2 were under pinyons, both of which had germinated; 4 were under junipers, 2 out of the 4 had germinated.

ACTIVITY AT CACHES

Opened pinyon seeds were found as early as February 6, but intermittent snow storms prevented weekly observations of cache sites until early March. Pinyon seeds opened by both birds and rodents were found in February.

Weekly observations of cache sites from March 10 to July 13, revealed many opened pinyon seeds at the sites in March (figure 5). The number of opened pinyon seeds decreased through mid-May then remained fairly constant through July. The large numbers of opened pinyon seeds found in the first survey (March 10) indicate that a substantial amount of cache recovery had occurred prior to that date. Since all opened pinyon seeds were removed after each survey, the seeds did not accumulate after the first survey. The majority of pinyon seeds found near the cache sites were opened by birds. Beginning in mid-April, a small number of seeds were found that had been opened by rodents. Rodents consumed a constant but low number of seeds through June.

Because of the large difference in the number of opened

seeds found between "popular" and "unpopular" trees, the two categories of trees were compared using the Mann-Whitney U test. Tree height, diameter, and litter below the canopy were found not to be significantly different in a comparison of 7 of the most "popular" and most "unpopular" pinyons ($U'=24.3$, $p>0.05$; $U'=31$, $p>0.05$; $U'=36$ $p>0.05$ respectively). Possibly other parameters other than those measured in this study such as canopy-base height or number of cones per tree are influential in promoting high caching activity.

DISTRIBUTION OF YOUNG PINYONS

Two general patterns emerge from examining the distribution of young pinyons: 1) pinyons are found in decreasing abundance in the four habitat types pinyon>juniper>bush>open (figure 6). 2) the abundance of pinyon is inversely related to habitat availability. Habitat availability for all except pinyon occurred in increasing order of abundance (figure 7).

A comparison of habitat usage by young pinyons relative to the availability of that habitat shows that young pinyons are found in disproportionately large numbers under pinyon and juniper trees and in disproportionately small numbers under bushes and in the open (figure 8).

Upon examination of the locations of young pinyons in relation to the meadows, two of the areas examined contain significantly more pinyons on the north side of the meadows (X^2

$=43.6$, $p<0.001$; $X^2=18.98$, p,0.001) while one area contains no significant difference between the numbers of pinyons on the north and the south side of the meadows ($X^2=3.36$, 0.1,p,0.5) (figure 9).

The distribution of young pinyons in the 3 areas surrounding meadows was no different from the distribution of young pinyons within tree canopy for the pinyon, juniper, and bush habitat types ($X^2=0.44$, $0.50<p<0.75$; $X^2=0.02$, $0.75<p<0.90$; $X^2=2.28$, $0.1<p<0.25$ respectively). However, there were significantly more pinyons near bushes in the areas surrounding meadows ($X^2=6.76$, $0.005<p<0.01$). This difference in distribution coincides with the observation that there are many more bushes in the meadows than in tree canopy (figure 10).

GERMINATION AND SURVIVAL OF PLANTED PINYONS

No planted seeds germinated until late July; most germinated during August. The timing of germination appears to be related to the timing of the monsoon season. Although some rain did occur on July 15, 16, and 20, the monsoon season did not begin until July 23. Of the seeds planted under cages, 1 had initially germinated under tree canopies (89 germinated by September), 3 had germinated near bushes (33 germinated by September), and 2 had germinated in the open (4 germinated by September). Of the seeds not planted under cages, 5 had initially germinated under tree canopies (12 germinated by September), and none had

germinated either near bushes or in the open in July. One pinyon seed germinated near bushes, and one germinated in the open by September.

Differences between germination and survival of caged pinyons under pinyon canopy, near bushes, and in the open were significant ($X^2 = 89.36$, $p<0.001$). Eighty-nine pinyon seeds (36%) germinated under pinyons, 33 seeds (13%) germinated near bushes, and 4 seeds (2%) germinated in the open (figure 11).

Differences between germination and survival of non-caged pinyons in the three vegetation types were also significant ($X^2 = 19.2$, $p<0.001$). Thirteen pinyon seeds (5%) germinated under pinyon canopy, 1 seed (0%) germinated near bushes, and 1 seed (0%) germinated in the open.

Although fewer non-caged pinyon seeds germinated than caged seeds in all three vegetation types, a statistical comparison between these two categories of pinyon seeds cannot be justified since the methods of planting the pinyons were different, so other factors beyond that of predation come into play on pinyon seed germination.

One factor which may have influenced the better germination and survival of the caged pinyon seed was that they were protected from predation after germinating. Therefore these results are of pinyon seeds that not only germinated but also escaped predation after germinating during the month of August.

DISCUSSION

The small number of caches still containing seeds in the fall, along with the small number of uncaged planted seeds that germinated indicate that although large numbers of pinyon seeds are cached by scrub jays during years of "bumper" seed crops, only a small proportion of these seeds germinate and survive the following summer. Both the jays and rodents such as *Peromyscus* spp. appear to be responsible for the retrieval of these cached seeds.

Since the majority of opened pinyon seeds found near the caches were opened by birds, the scrub jays appear to be adept at relocating and consuming their caches. However, extrapolating information solely from the amount of opened seeds nearby will be biased toward animals that open the seeds on location. Other seed predators may find a cache then transport and consume the seed in another area.

The impact of these other predators can better be evaluated by the differences in germination between the caged and non-caged seeds. These data suggest that seed predation by rodents is much more influential than the data from examination of opened seeds indicate. It is very unlikely that the jays found the planted seeds since scrub jays have been found to use spatial memory rather than olfaction to locate their caches (Kamel and Balda, pers com.) So if they did not cache the seeds themselves, they would not be able to find them.

Peromuscus maniculatus and *P. trueii* preside within the

pinyon-juniper woodlands, and both rely on pinyon seeds as a food source (Williams 1959). Unlike the Corvids, they rely heavily on olfaction to detect food (Howard et al. 1968). They are able to efficiently locate and dig up shallow caches of pinyon seeds. Floyd (1981) found that 100% of the Pinus edulis seeds she planted under pinyon were removed by P. maniculatus when they were left on the ground's surface, were planted 3cm below the surface, or were planted 5cm below the surface. Density of the planted seeds did not have an effect on predation. She also found that cover type was important in seed retrieval by Peromyscus spp. Of 10 caches she made under 3 cover types, all seeds planted under pinyons were removed by Peromyscus spp, 2 planted under sagebrush were removed, and none planted under oak were removed. Analysis of data from both the present study and from that of Floyd indicate that caches of pinyon seeds are heavily preyed upon by Peromyscus spp., and those under pinyon canopy are removed most intensively.

However, some do escape predation as indicated by the non-caged seeds planted under pinyons that germinated and the four unrecovered bird caches also under pinyons, all of which germinated. This study affirms that scrub jays cache under pinyons more than under any other vegetation type, that pinyons germinate best under pinyon canopy, and that the distribution of young pinyons is predominantly under pinyons in spite of the higher availability of other vegetation types. The high caching intensity, and the successful germination and survival under pinyons appear to outweigh the effects of intense predation under

pinyons. Consequently pinyon canopy appears to be the site of the most intensive pinyon regeneration.

Juniper canopy also appears to be important in pinyon regeneration as indicated by the large numbers of young pinyons under juniper canopy and the observations of jays caching under juniper. Juniper canopy was not included in the germination experiment, so pinyon predation and germination under junipers could not be evaluated.

Since jays cached near bushes, and a fair number of young pinyons were found near bushes, bushes also seem important in pinyon regeneration. The germination experiment reveals that pinyon seeds planted near bushes can potentially germinate, but pinyon seeds not protected by a cage have little germination and survival success. Both bushes and tree canopies are good locations for young pinyons because they reduce light intensity and temperature extremes (Little 1977). Bushes are more advantageous for young pinyons as nurse plants than trees because they do not keep as much moisture away from the pinyons and their shorter height allows the pinyons to eventually "top out" over the bushes and receive more sunlight once they are better established (Meeuwig and Bassett 1983).

Although jays were observed caching in the open more than under junipers or near bushes, very few seeds germinated in the open. The one unrecovered cache in the open had not germinated while all four under pinyons had germinated. Also, very few planted seeds germinated and survived in the open, and few young pinyons were found in the open. Open areas appear to be poor

sites for pinyon germination and survival. Little (1977) states that open areas and grasslands are not good habitats for seedlings, which are more often found in the protective cover of shrubs of parent trees. Meagher (1943) also found that survivorship was lower for pinyons that were not protected by shade.

The experiment on pinyon germination was only conducted during one year with a limited number of germination sites. Planting pinyons in more germination sites and planting them under junipers as well as the other vegetation types would enhance the finding of this study. Since environmental conditions vary from year to year, germination results could be affected by the weather patterns of that particular year. The timing of germination was undoubtably affected by the late onset of the monsoons. Meagher (1943) found that watering influenced timing of germination such that the watered seeds germinated 2 weeks before the unwatered seeds which germinated 2 weeks after the monsoons began. Although water availability affected the timing of germination, it did not affect the percent germination in Meagher's study. Therefore the germination results of this study would probably not vary if the study was conducted in a different year, except for the timing of germination.

One problem encountered during this study was the extreme difficulty in observing scrub jays away from the meadows. Consequently practically all the caches were observed at or near the meadows. Scrub jays undoubtedly cache seeds well within the pinyon-juniper forest. Since pinyons and junipers grow fairly

close together, the vast majority of caches within the trees would be under either pinyon or juniper canopy. Therefore a higher proportion of all caches are likely to be under pinyons and junipers than indicated in this study.

A long-term study on scrub jays would be beneficial, especially since it could note changes in caching activity between years with different sized cone crops. Studying the jays in different areas would also be beneficial for it would allow one to compare caching activity between habitats. Also, and in-depth study on seed predation by Peromyscus would illuminate their influence on cached seeds and therefore on pinyon regeneration.

In a comparison of dependence on pinyon seeds by Clark's nutcrackers, pinyon jays, Steller's jays, and scrub jays, scrub jays have been considered the least dependent on pinyon seeds (Vanderwall and Balda 1981). The bulk of Clark's nutcrackers and pinyon jays' winter diet from November to February consists of conifer seeds (80-100% of the Clark's nutcracker's diet, and 70-90% of the pinyon jay's diet) (Giuntoli and Mewaldt 1978, Ligon 1978). The Clark's nutcracker's diet consists entirely of conifer seeds during March and April. These seeds primarily come from caches. The timing of the Clark's nutcrackers and pinyon jays' breeding season is influenced by the size of the previous cone crop, a situation which exemplifies the birds' dependence on pinyon seeds (Vanderwall and Balda 1981, Ligon 1978). Still, with this high dependency on pinyon seeds, many caches are unrecovered and are able to germinate; however, most of the germination sites

are outside of the pinyon-juniper woodlands. The pinyon jays that are residents of pinyon-juniper woodlands would appear to be influential in pinyon regeneration; those living in the ponderosa pine forest as well as the Clark's nutcrackers, which live in the mixed coniferous forest are not important in local pinyon regeneration. No in-depth studies have been done on the dependence of Steller's jays on pine seeds; it has been suggested that pine seeds are an important source of energy during the winter (Vanderwall and Balda 1981). However, since Steller's jays transport the seeds into the ponderosa pine forest, unrecovered caches would be unimportant in local pinyon regeneration. Of these Corvids, the pinyon jays living in the pinyon-juniper woodlands and the scrub jays appear to be the most important in pinyon regeneration.

No data are available on observations of cache recovery in natural populations of these Corvids on the pinyon-juniper woodlands. The findings in this study, that scrub jays cache most often in the best pinyon germination sites, and that 8 percent of the identified caches were not recovered by scrub jays or by foraging mice indicate that scrub jays are important agents for pinyon regeneration.

Satisfactory pinyon regeneration is often difficult to achieve, but is necessary if sustained tree cover is to be maintained. Understanding scrub jay behavior and cache characteristics would be important for woodland management, especially since the birds seem to select satisfactory pinyon regeneration microsites for cache sites.

Although this study concentrated on caching sites adjacent to meadows, additional information on caching behavior and seedling survival within stands or in small openings and in slash covered harvested areas would be of value. Information from this and future studies could be incorporated into woodland management plans. More research is needed, but one could speculate that areas which are favored for cache sites could be identified and maintained until sufficient pinyon regeneration has occurred in the particular region. If the characateristics of "popular" trees were determined, these trees or groups of trees could be retained under a single-tree selection method to encourage caching. These trees could then be harvested when the resulting regeneration was large enough. Small openings have a less severe microclimate than large meadows; it is possible that areas of certain sizes may be more conducive to caching and satisfactory regeneration. Any management scheme would have to maintain satisfactory habitat for nesting, breeding, as well as for seed caching. Management could attempt to optimize the general habitat in order to encourage or maintain the scrub jay population.

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FIGURE 1. LOCATIONS OF CACHE SITES

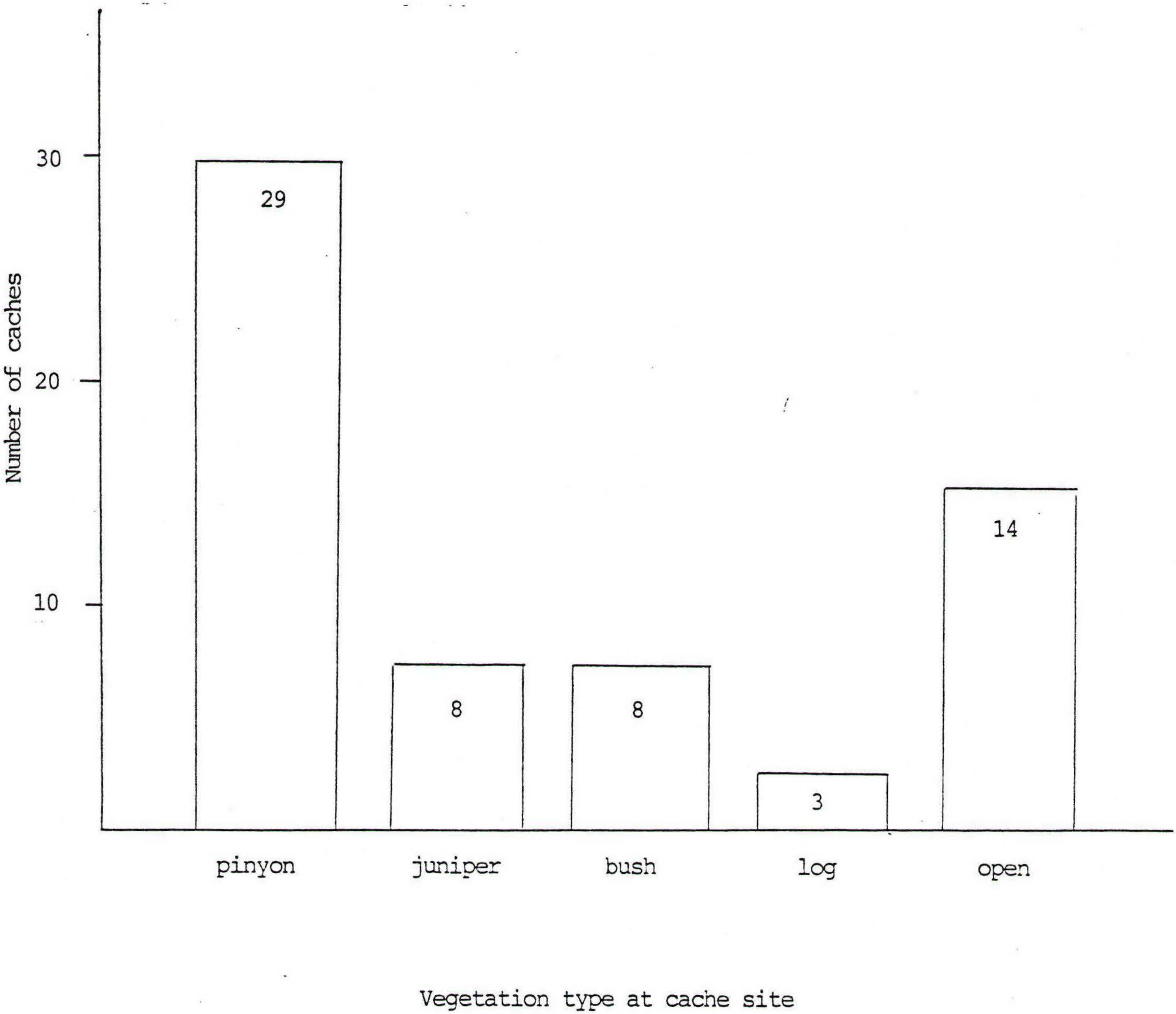
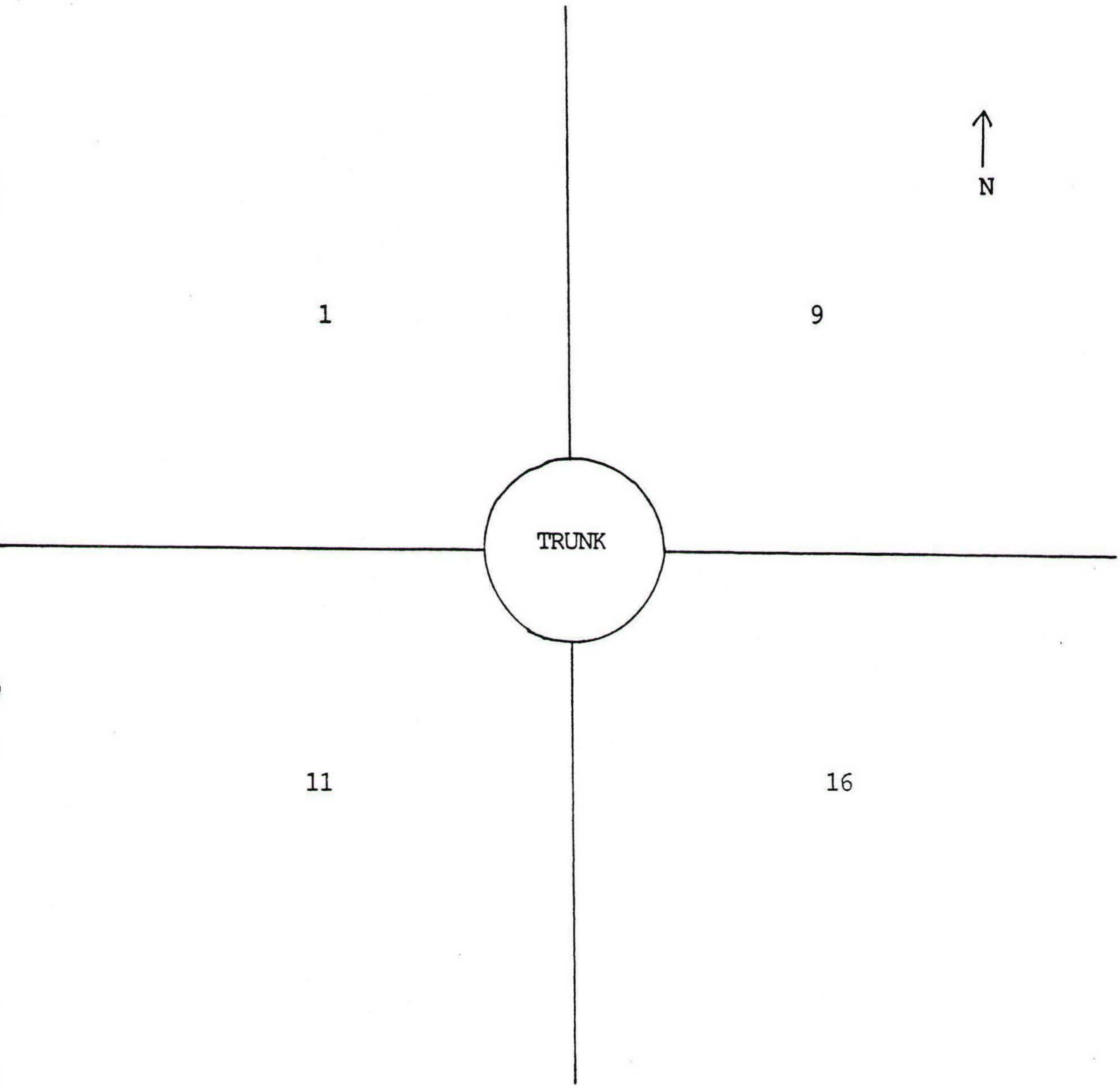


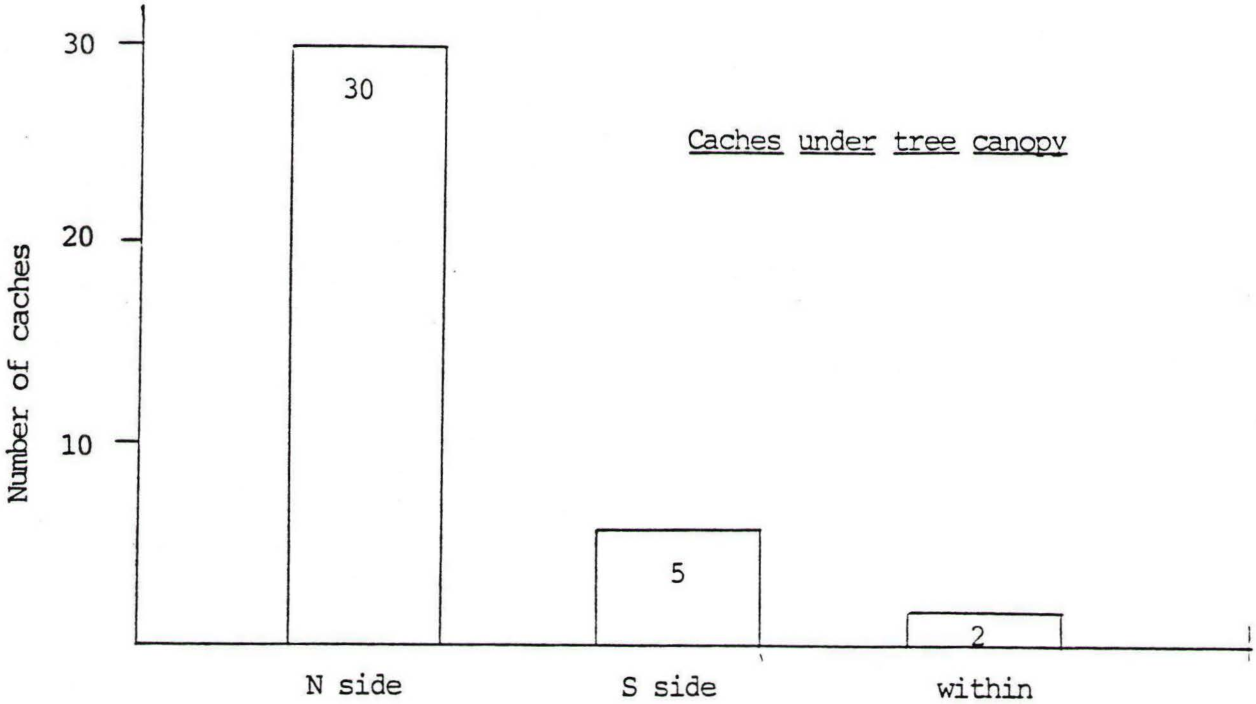
FIGURE 2. COMPASS ORIENTATION OF CACHE TO NEAREST TRUNK



Orientations of caches around the tree trunk were significantly different.

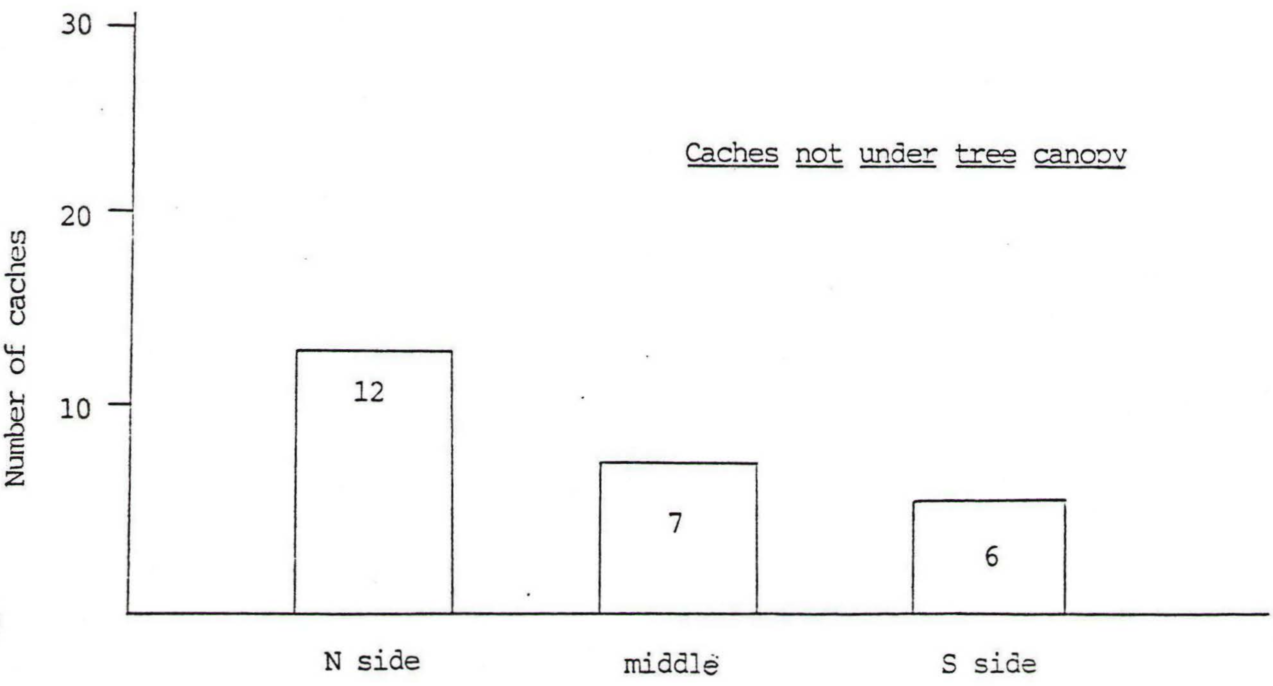
X^2=14.05, p<0.005

FIGURE 3. CACHES IN RELATION TO MEADOWS



$X^2=17.86$, $p<0.001$

FIGURE 4.



$X^2=2.00$, $0.1<p<0.25$

FIGURE 5. PINYON SEED FRAGMENTS FOUND AT THE CACHE SITES MARCH THROUGH JULY 1987

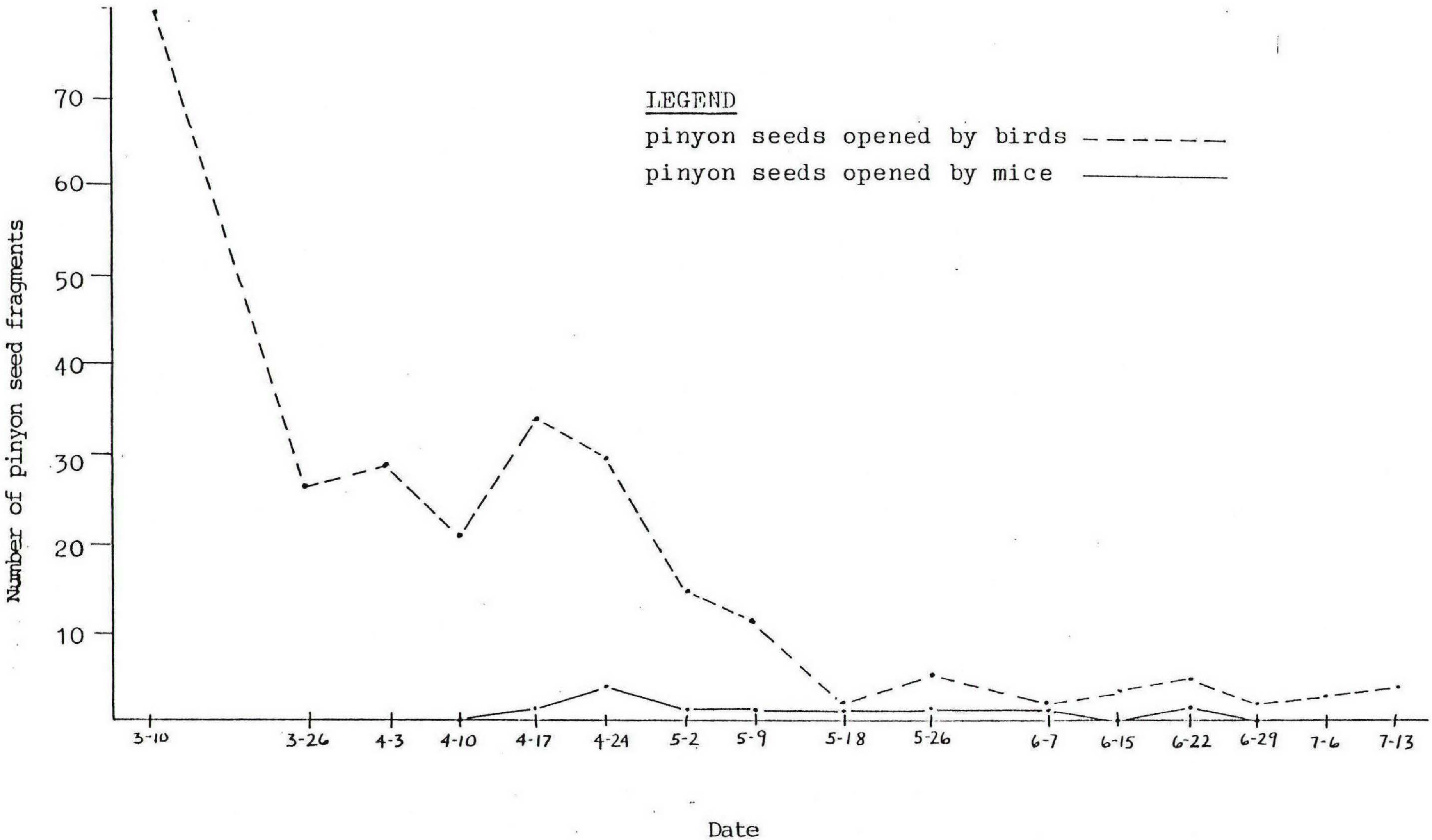
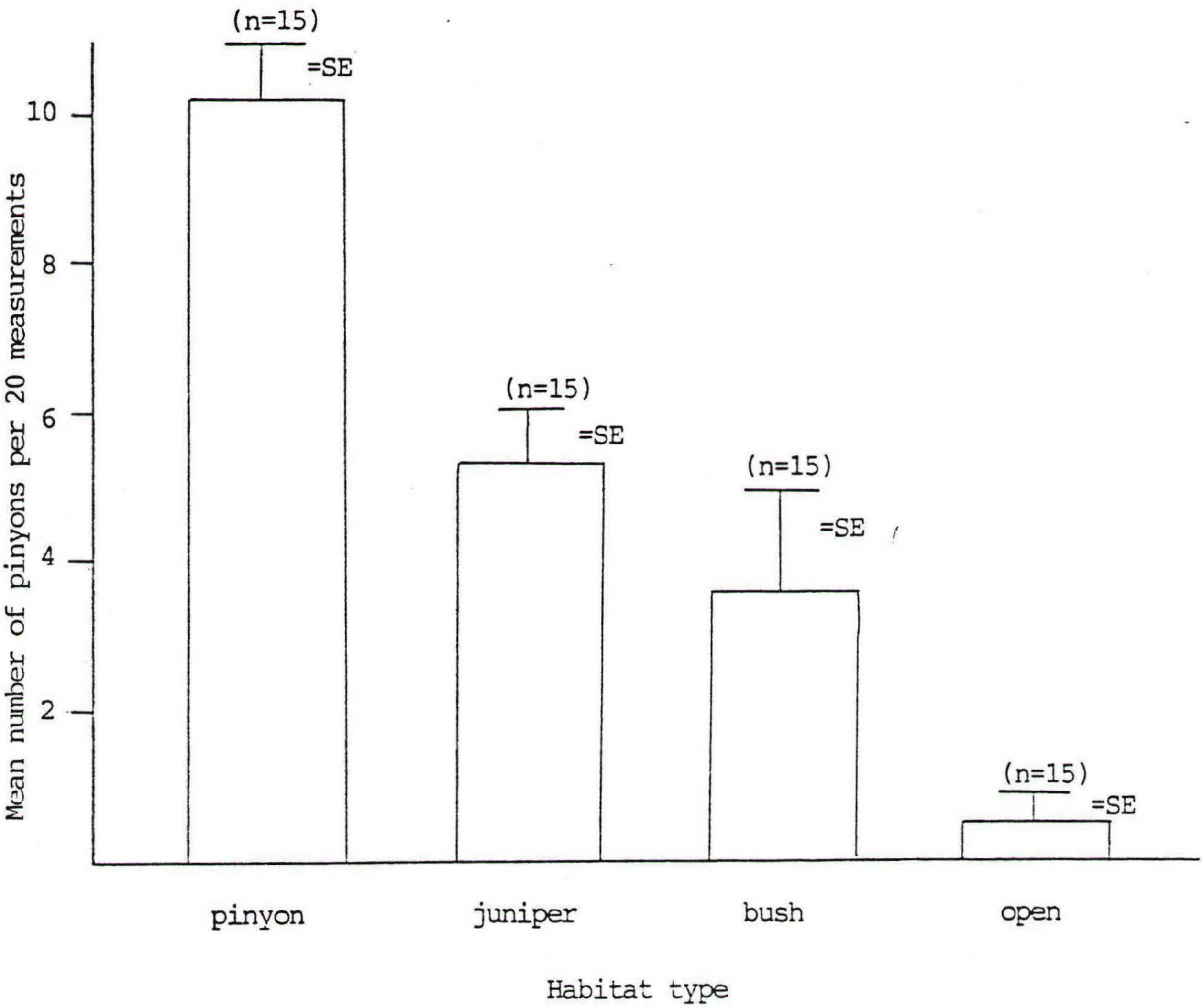


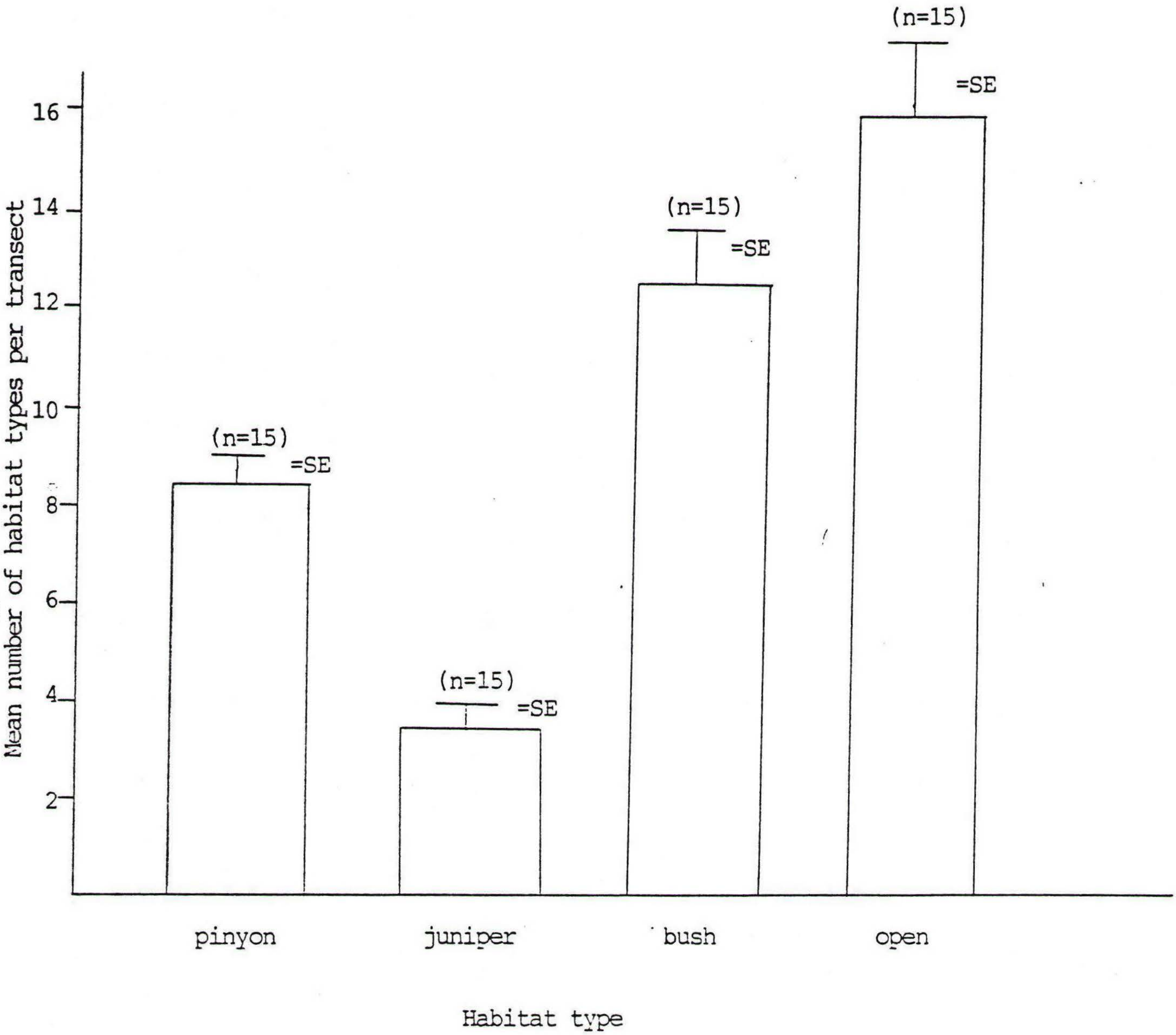
FIGURE 6. THE DISTRIBUTION OF YOUNG PINYONS IN 4 HABITAT TYPES



pinyon = P
juniper = J
bush = B
open = O

CONTRAST	P-VALUE
P J	0.0003 s
P B	0.0000 s
P O	0.0000 s
J B	0.2259 ns
J O	0.0006 s
B O	0.0199 s

FIGURE 7. HABITAT AVAILABILITY OF 4 HABITAT TYPES



pinyon = P
juniper = J
bush = B
open = O

CONTRAST	P-VALUE
P J	0.0040 s
P B	0.0268 s
P O	0.0010 s
J B	0.0000 s
J O	0.0000 s
B O	0.0819 ns

FIGURE 8. PINYON ABUNDANCE IN RELATION TO HABITAT AVAILABILITY

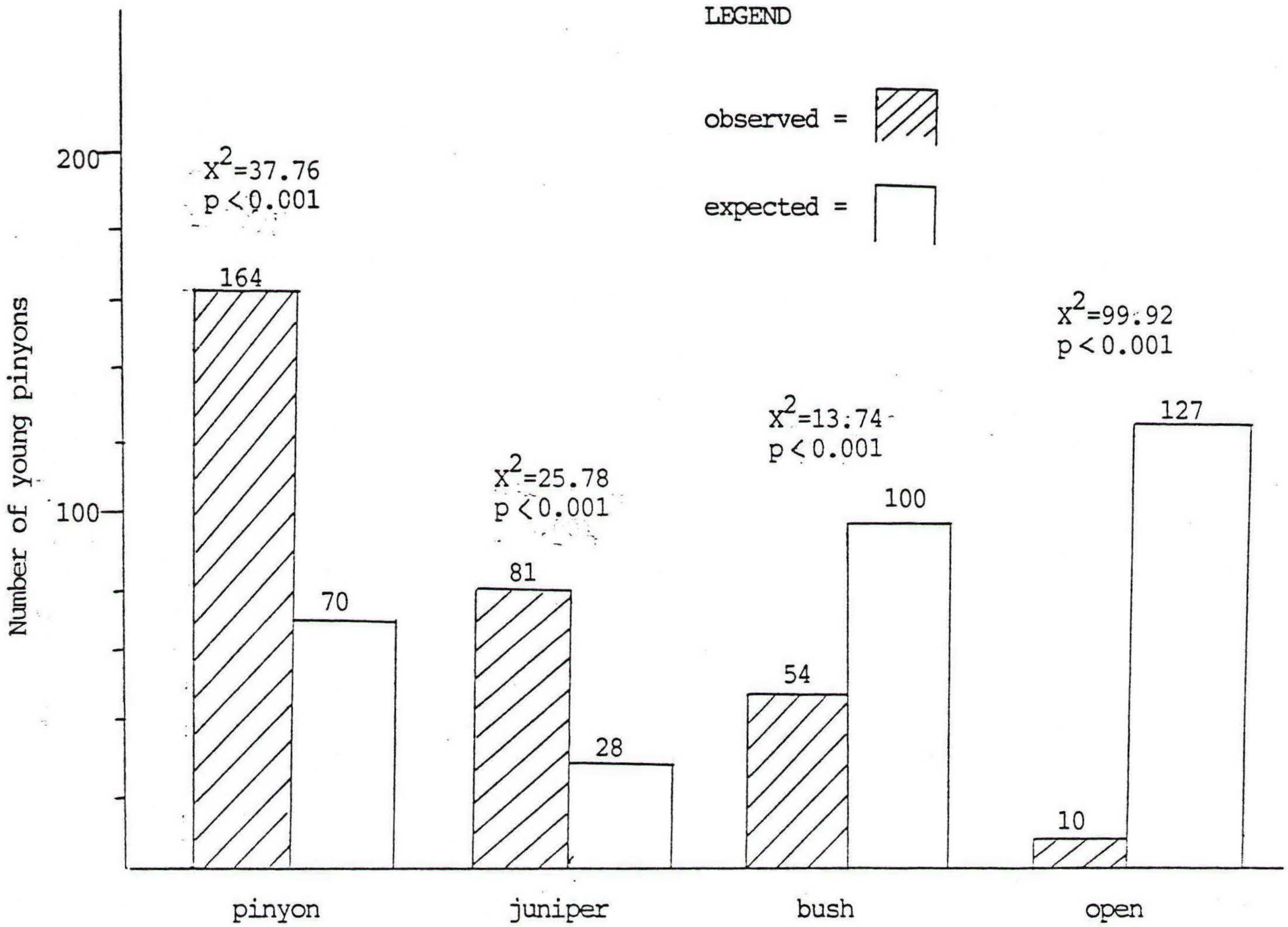


FIGURE 9. DISTRIBUTION OF YOUNG PINYONS IN RELATION TO MEADOWS

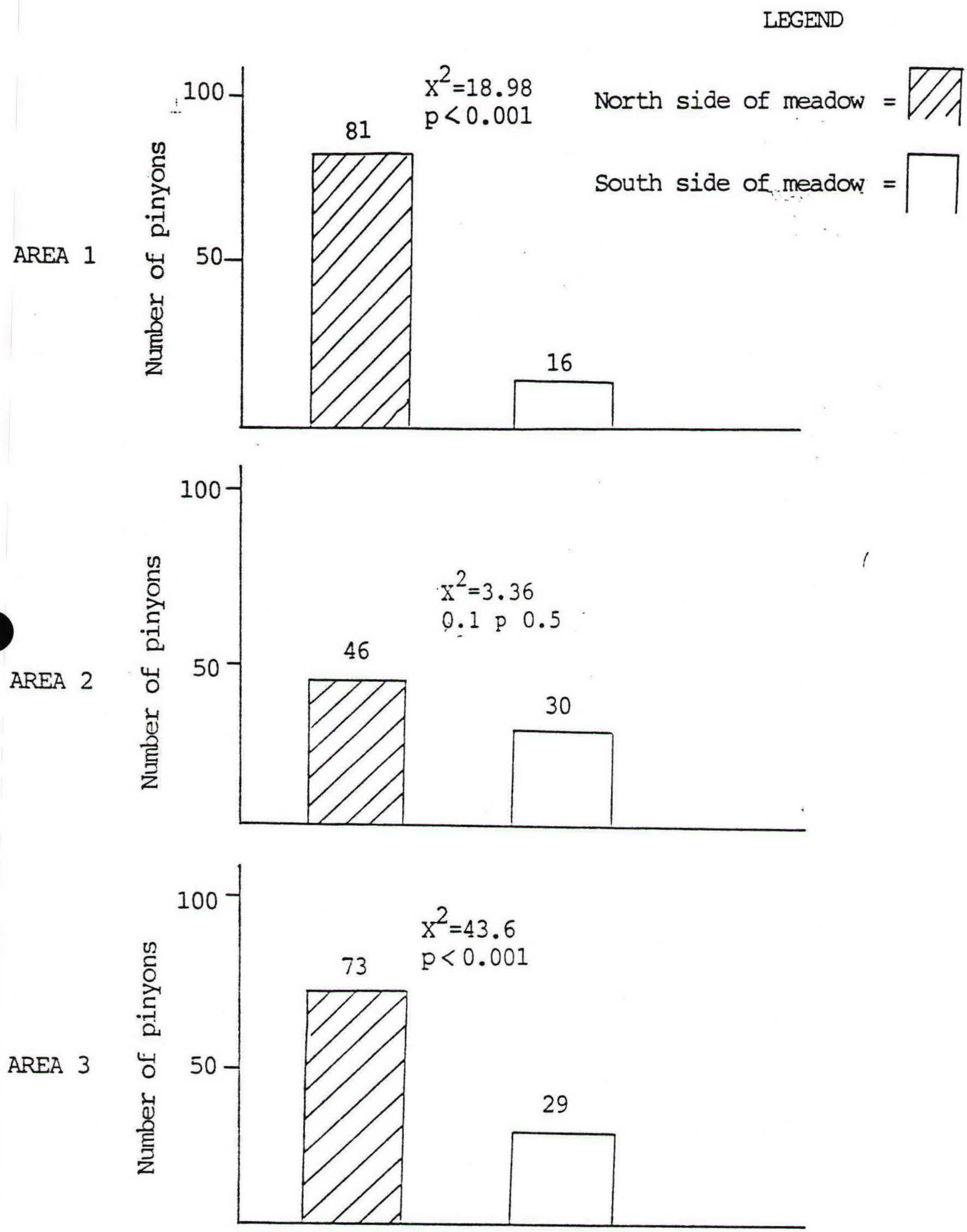


FIGURE 10. DISTRIBUTION OF YOUNG PINYONS IN THREE SITES SURROUNDING MEADOWS COMPARED TO ONE SITE COMPLETELY WITHIN TREES

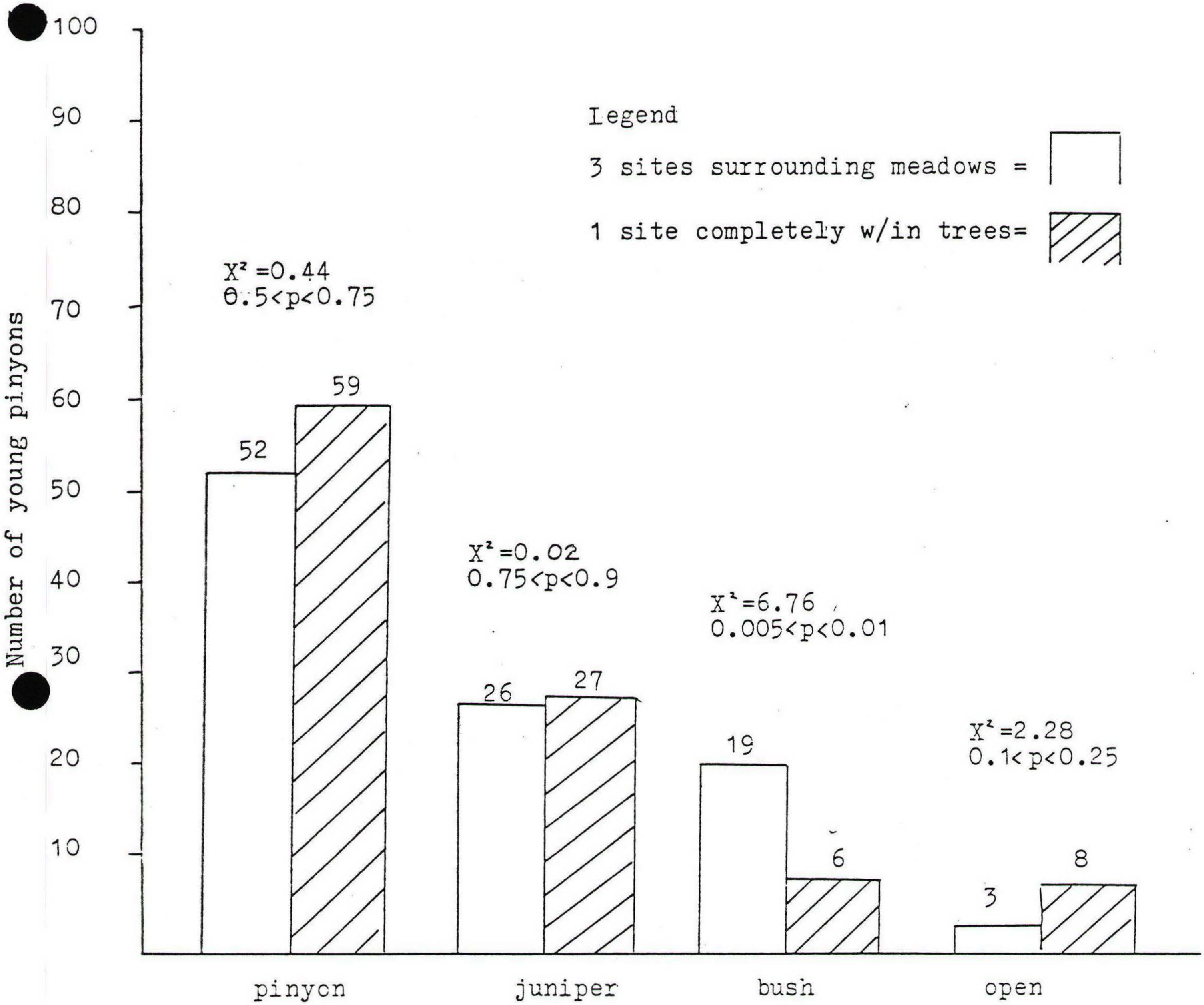
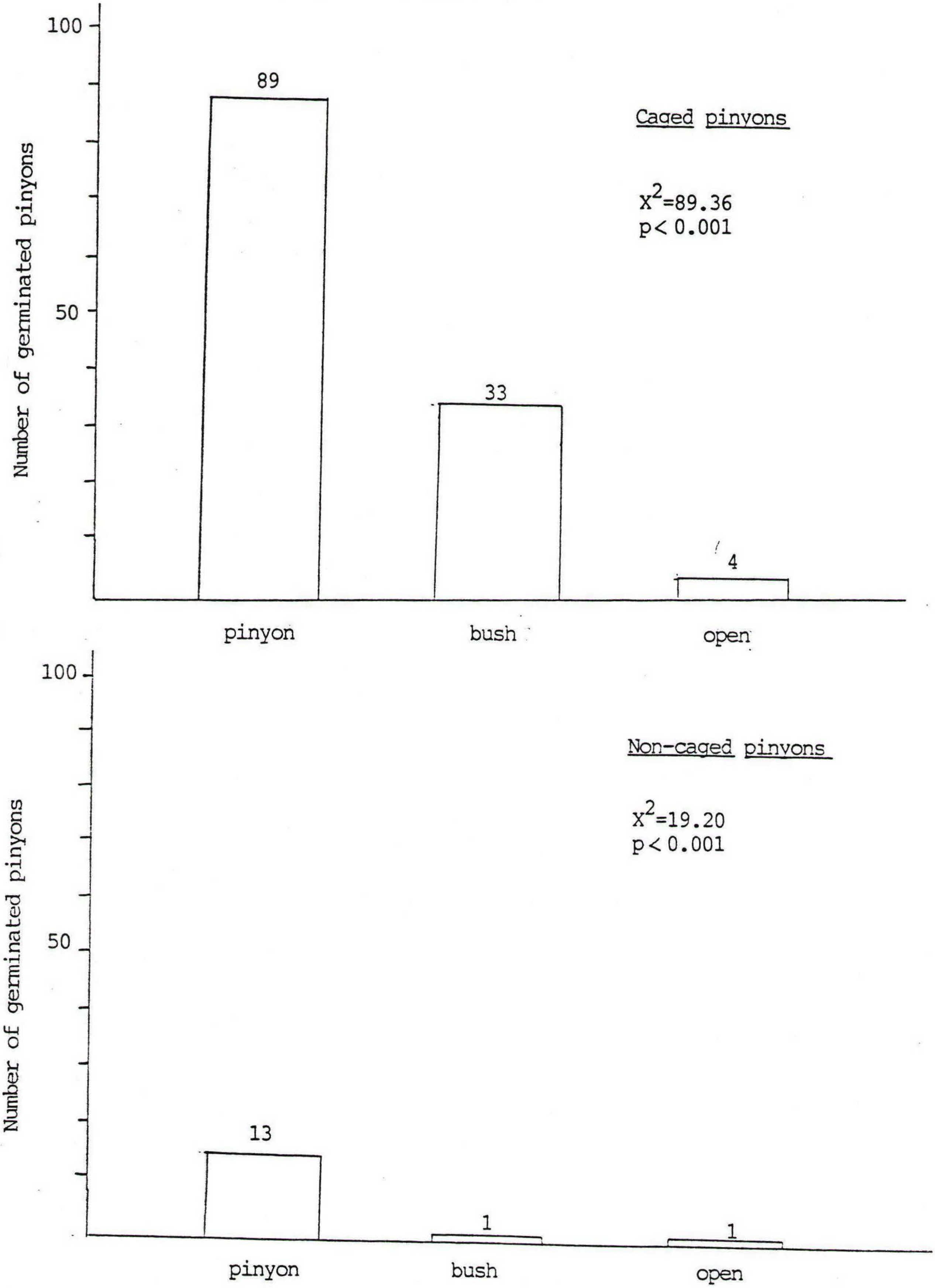


FIGURE 11. GERMINATION AND SURVIVAL OF CAGED AND NON-CAGED PINYONS IN THREE VEGETATION TYPES



BLUE (Chronological File) 1972

Hoover
Bergen
Frank
Gary
Haeffner

Leaf
Schultz
Moore
Florquist

January 1 to December 31, 1972

1602 Hoover